International Journal of Applied Mathematics
& Statistical Sciences (IJAMSS)
ISSN 2319-3972
Vol. 2, Issue 4, Sep 2013, 45-52

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

EFFECT OF CHEMICAL REACTION ON MHD FREE CONVECTION ON KUVSHINSHKI FLUID THROUGH POROUS MEDIUM IN PRESENCE OF HEAT RADIATION WITH CONSTANT HEAT AND MASS FLUX ACROSS MOVING PLATE

N. SENAPATI[1], R. K. DHAL[2] & K. RAY[3]

[1]Department of Mathematics, Ravenshaw University, Cuttack, Orissa, India

[2]J.N.V. Paralakhemundi, Gajapati, Orissa, India

[3]Indira Woman College, Tulasipur, Cuttack, India

ABSTRACT

Effect of chemical reaction on MHD free convection on kuvshinshki fluid through porous medium in presence of heat radiation with constant heat and mass flux across moving plate. has been studied. Solutions are obtained for velocity, temperature, concentration; and skin friction parts. The result of various material parameters are discussed on flow variables and presented by graphs and table.

KEYWORDS: Kuvshinshki Fluid, Porous Medium, Heat Radiation, Heat and Mass Flux, MHD and Chemical Reaction

1. INTRODUCTION

MHD plays an important role in power generation, space propulsions, cure of diseases, control of thermonuclear reactor, boundary layer control in field of aerodynamics .In past few years several simple flow problems associated with classical hydrodynamics have received new attention within the more general context of hydrodynamics. Convection in porous medium has applications in geothermal energy recovery, oil extraction and thermal energy storage. The effect of magnetic field on free convection flow is important in liquid–metals and ionized gases. The flow through porous media has become an important topic because of the recovery of crude oil from pores of reservoir rocks .From the primitive years mass transfer plays an impotent role in vaporization of ocean, burning of pool of oil, spray drying, leaching and abolition of a meteorite. The process of heat and mass transfer in free convection flow have attracted the attention of a number of scholars due to their application in many branches of science and engineering, viz. in the early stages of melting adjacent to a heated surface, in chemical engineering processes which are classified as a mass transfer process, in a cooling device aeronautics, fluid fuel nuclear reactor. The study of fluctuating flow is important in the paper industry

Free convection effect on flow past a vertical surface studied by Vajnvelu et al [1], Vedhanayagam [2] and others with different boundary conditions. Revankar et al [3] and many workers have studied hydro magnetic natural convection flow past a vertical surface. Mohapatra and Senapati [4] have considered the steady MHD free convection flow through a porous medium with mass transfer. Mohapatra and Senapati [5, 6] have investigated the unsteady MHD free convection flow with mass transfer through porous medium past a vertical plate. Senapati et.al[8] have studied magnetic effect on mass and heat transfer of a hydrodynamic flow past a vertical oscillating plate in presence of chemical reaction. Senapati et.al [9] also discussed the chemical effects on mass and heat transfer on MHD free convection flow of fluids in vertical plates and in between parallel plates in poiseuille flow. Vashney et al[7] studied the Effect of Kuvshinshki fluid on MHD free convection flow through a porous medium bounded by an oscillating porous plate in slip flow regime with heat source/sink and transpiration.

It is proposed to study the effect of chemical reaction on MHD free convection on kuvshinshki fluid through porous medium in presence of heat radiation with constant heat and mass flux across moving plate.

2. FORMULATION OF THE PROBLEM

An unsteady free convection two dimensional Kuvshinshki flow through porous medium with constant heat and mass flux past an infinite vertical plate in chemical reaction and radiation is considered. The X'-axis is taken along the plate in vertical upward direction and Y'-axis is taken normal to it. A magnetic field of uniform strength H_0 is applied normal to the plate. The effect of induced magnetic field is neglected. The Reynolds number is assumed to be small. Further the viscous and joulean dissipation are neglected in energy equation. .Initially surrounding fluids are at rest and are the temperature T'_∞ and mass concentration C'_∞ at all points. Fluid has constant heat and mass flux across the moving plate of velocity U_0. Since the plate is considered infinite along X' direction, all physical quantities will be independent of x'. The fluid properties are assumed constant except for the influence of density in body force term. Under these assumptions, the physical variables are function of y' and t' only. Temperature and mass concentration changes with the distance from plate. Then by usual boundary layer approximation the unsteady flow governed by following equations.

$$\frac{\partial v'}{\partial y'} = 0 \Rightarrow v' = -v_0 \tag{1}$$

$$\left(1+\lambda_0\frac{\partial}{\partial t'}\right)\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = g\beta(T'-T'_\infty) + g\beta_c(C'-C'_\infty) + \nu\frac{\partial^2 u'}{\partial y'^2} - \left(\frac{\sigma B_0^2}{\rho}+\frac{\nu}{K'}\right)u'\left(1+\lambda_0\frac{\partial}{\partial t'}\right) \tag{2}$$

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = k\frac{\partial^2 T'}{\partial y'^2} + \frac{S'}{\rho C_p}(T'-T'_\infty) - \frac{1}{\rho C_p}\frac{\partial q}{\partial y'} \tag{3}$$

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - R'(C'-C'_\infty) \tag{4}$$

with corresponding boundary conditions

$$\left.\begin{aligned} & y' = 0; u' = U_0\, \frac{dT'}{dy'} = -\frac{q}{\lambda}, \frac{dC'}{dy'} = -\frac{m}{D} \\ & \text{as } y' \to \infty : u' \to 0, T' \to T'_\infty, C' \to C'_\infty \end{aligned}\right\} \tag{5}$$

Let us introduce the following non dimensional quantities

$$\left.\begin{aligned} & \eta = \frac{v_0 y'}{\nu}, f(\eta) = \frac{u'}{v_0}, \theta = \frac{(T'-T'_\infty)v_0\lambda}{q\nu}, Q = \frac{U_0}{v_0}, Pr = \frac{\mu C_p}{\lambda}, Sc = \frac{\nu}{D} \\ & C = \frac{(C'-C'_\infty)V_0 D}{m\nu}, t = \frac{t' v_0^2}{\nu}, K = \frac{v_0^2 K'}{\nu^2}, M = \frac{\sigma B_0^2 \nu}{\rho v_0^2}, Gr = \frac{g\beta q \nu^2}{v_0^4 \lambda}, \\ & Gm = \frac{g\beta_c m \nu^2}{v_0^4 D}, \lambda_1 = \frac{\lambda_0 v_0^2}{\nu}, S = \frac{S'\nu^2}{v_0^2\lambda}, N = \frac{4\sigma * T_\infty^3}{k * k} \text{ and } R = \frac{R'\nu}{v_0^2} \end{aligned}\right\} \tag{6}$$

where Gr is Grashof number, Gm modified Grashof number, M is magnetic number, Pr is Prandtl number, Sc is Schmidt number, θ is non-dimensional temperature, C is non-dimensional mass concentration, K is porosity parameter N is the radiation parameter,R is chemical reaction parameter, S is heat source parameter, Q is velocity ratio parameter and λ_1 is viscoelastic parameter.

With the help of equation (6) the equations (2) to (5) reduce to

$$-\left[1+\lambda_1\left(M+\frac{1}{K}\right)\right]\frac{\partial f}{\partial t}+\frac{\partial^2 f}{\partial \eta^2}+\frac{\partial f}{\partial \eta}-\lambda_1\frac{\partial^2 f}{\partial t^2}-f\left(M+\frac{1}{K}\right)=-Gr\theta-GmC \tag{7}$$

$$-Pr\frac{\partial \theta}{\partial t}+Pr\frac{\partial \theta}{\partial \eta}+\left(1+\frac{4N}{3}\right)\frac{\partial^2 \theta}{\partial \eta^2}+S\theta=0 \tag{8}$$

$$-Sc\frac{\partial C}{\partial t}+\frac{\partial^2 C}{\partial \eta^2}+Sc\frac{\partial C}{\partial \eta}-RC=0 \tag{9}$$

with corresponding boundary conditions

$$\left.\begin{aligned} &f=Q\ ,\theta'=-1\ ,C'=-1\ for\ \eta=0\\ &f\to 0\ ,\theta\to 0\ ,C\to 0\quad as\ \eta\to\infty \end{aligned}\right\} \tag{10}$$

METHOD OF SOLUTION

To solve the governing equations let us introducing the following exponential series

$$\left.\begin{aligned} f(\eta,t)&=f_0(\eta)e^{-nt}\\ \theta(\eta,t)&=\theta_0(\eta)e^{-nt}\\ C(\eta,t)&=C_0(\eta)e^{-nt} \end{aligned}\right\} \tag{11}$$

Substituting equation (11) in Equation (7) to (8), we get

$$f_0''+f_0'-\left(M+\frac{1}{K}-n\right)(1-n\lambda_1)f_0=-Gr\theta_0-GmC_0 \tag{12}$$

$$\left(1+\frac{4N}{3}\right)\theta_0''+Pr\theta_0'+(nPr+S)\theta_0=0 \tag{13}$$

$$C_0''+ScC_0'+(nSc-R)C_0=0 \tag{14}$$

with corresponding boundary conditions

$$\left.\begin{aligned} &f_0=Q\ ,\theta_0=-1\ ,C_0=-1\ for\quad \eta=0\\ &f_0\to 0\ ,\theta_0\to 0\ ,C_0\to 0\quad as\quad \eta\to\infty \end{aligned}\right\} \tag{15}$$

By solving equations from (12) to (14) using boundary conditions (15) we get

$$f_0=(Q+A_4Gr+A_5Gm)e^{-A_3\eta}-GrA_4e^{-A_2\eta}-GmA_5e^{-A_1\eta} \tag{16}$$

$$\theta_0 = \frac{e^{-A_2\eta}}{A_2} \tag{17}$$

$$C_0 = \frac{e^{-A_1\eta}}{A_1}, \tag{18}$$

Where $A_1 = \frac{1}{2}\left(Sc + \sqrt{Sc^2 - 4(nSc - R}\right)$

$$A_2 = \left(Pr + \sqrt{Pr^2 - 4(nPr + s)(1 + \left(\frac{4N}{3}\right))}\right) / \left(2(1 + \left(\frac{4N}{3}\right)\right)$$

$$A_4 = \frac{1}{(A_2^2 - A_2 - M_1)}, A_5 = \frac{1}{(A_1^2 - A_1 - M_1)}, M_1 = \left(M + \frac{1}{K} - n\right)(1 - n\lambda_1)$$

The skin friction/shearing stress at the plate in dimensional form is given by

$$\tau_0 = \left(\frac{\partial f_0}{\partial \eta}\right)_{\eta=0} = -A_3(Q + A_4 Gr + A_5 Gm) + A_2 Gr A_4 + A_1 Gm A_5 \tag{19}$$

Similarly, the rate of heat transfer at the plate/Nusselt Number is given by

$$Nu_0 = -\left(\frac{\partial \theta_0}{\partial \eta}\right)_{\eta=0} = 1$$

and the rate of mass concentration transfer at the plate/Sherwood Number is given by

$$Sh_0 == -\left(\frac{\partial C_0}{\partial \eta}\right)_{\eta=0} = 1$$

4. RESULTS AND DISCUSSIONS

In this paper we have studied the Effect of chemical reaction on MHD free convection on kuvshinshki fluid through porous medium in presence of heat radiation with constant heat and mass flux across moving plate.. The effect of the parameters Gr, Gm, Q, M, R, K, N,S, Pr, n, λ_1 and Sc on flow characteristics have been studied and shown by means of graphs and tables. In order to have physical correlations, we choose suitable values of flow parameters. The graphs of velocities, heat and mass concentration are taken w.r.t η. Shearing Stress is obtained in the table for different parameters.

Velocity Profiles: The velocity profiles are depicted in Figures 1-4. Figure-(1) shows the effect of the parameters Gr, Gm *and* S on velocity at any point of the fluid, when Q=2, Sc=0.23, R=2, M=2, K=2, N=2, n=2 and Pr=071**.** It is noticed that the velocity decreases with the increase Grashoff number (Gr), where as increases with the increase of modified Grashoff number (Gm) and source parameter (S).

Figure-(2) shows the effect of the parameters M,n and K on velocity at any point of the fluid, when Q=2, Sc=0.23, R=2, Gr=2, Gm=2, N=2, S=2 and Pr=071. It is noticed that the velocity decreases with the increase of Magnetic parameter (M), exponential parameter (n) and permeability parameter porous medium (K).

Figure-(3) shows the effect of the parameters R ,Sc and N on velocity at any point of the fluid, when Q=2, Sc=0.23, M=2, Gr=2, Gm=2, K=2, S=2 and Pr=071. It is noticed that the velocity decreases with the increase of Schmidt number (Sc) and Radiation parameter (N)

where as increases with the increase of chemical reaction parameter (R).

Figure-(4) shows the effect of the parameters Pr, Q and λ_1 on velocity at any point of the fluid, when R=2, Sc=0.23, M=2, Gr=2, Gm=2, K=2, S=2 and Pr=071. It is noticed that the velocity decreases with the increase of viscoelastic parameter (λ_1) *and* Prandtl number (Pr) where as increases with the increase of velocity ratio parameter (Q).

Mass Concentration Profile: Figure-(5) shows the effect of the parameters Sc, n and R on mass concentration profile at any point of the fluid in the absence of other parameters.

It is noticed that the mass concentration decreases with the increase of Schmidt number (Sc), exponential parameter (n) and chemical reaction parameter(R).

Temperature Profile: Figure-(6) shows the effect of the parameters $\mathrm{Pr}, \mathrm{N}, \mathrm{n}$ and S on Temperature profile at any point of the fluid in the absence of other parameters.

It is noticed that the temperature falls in the increase of Prandtl number (Pr), exponential parameter (n) and Radiation parameter (N), whereas temperature fluctuate with the increase of Heat source parameter(S).

Table-(1) shows the effects of different parameters on Shearing stress .It is noticed that shearing stress decreases in the increase of Grashoff number (Gr), Prandtl number (Pr) and Heat source parameter (S), whereas increases in the increase of all other parameters.

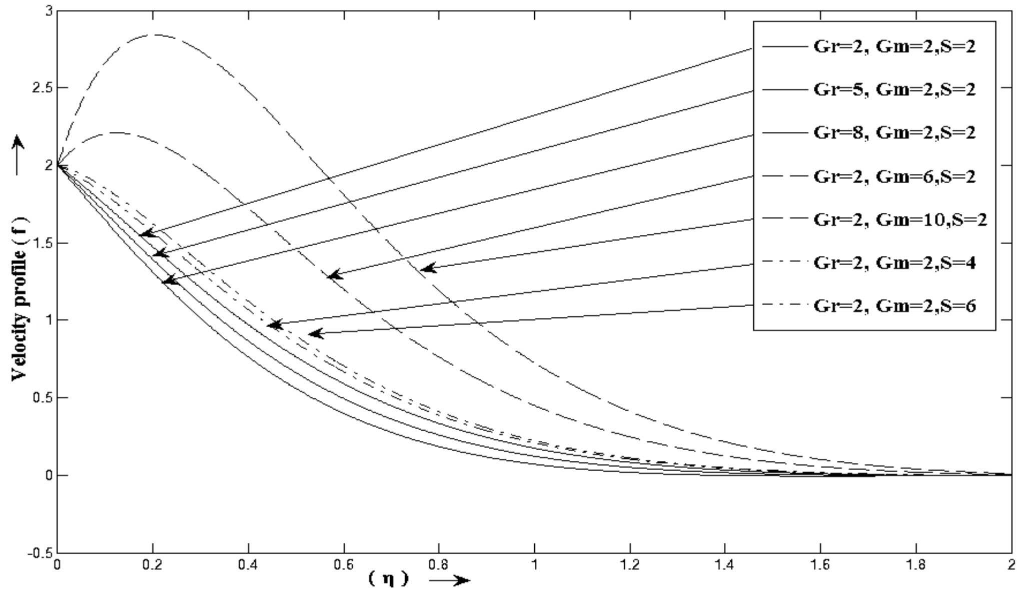

Figure 1: Effect of Gm, S and Gr on Velocity Profile (f), When Q=2, Sc=0.23, R=2, M=2, K=2, N=2, n=2 and Pr=071

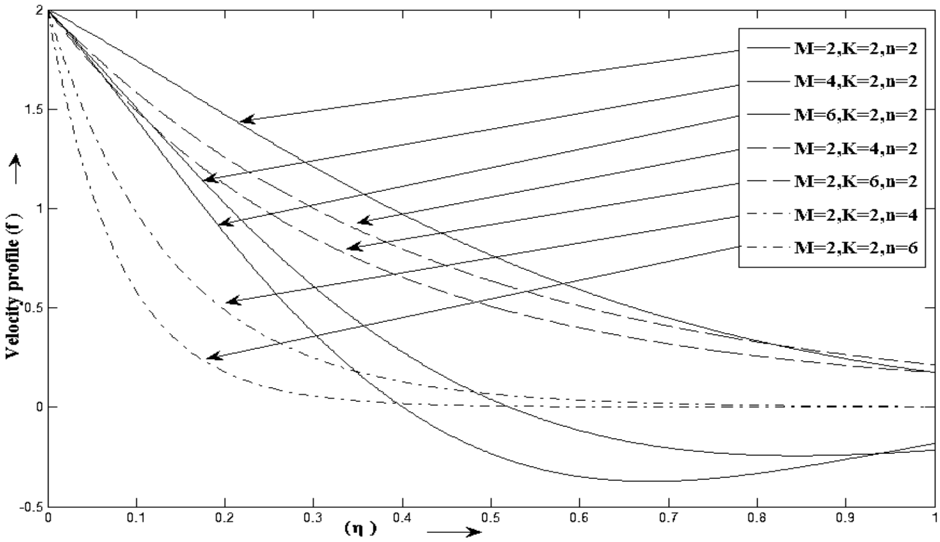

Figure 2: Effect of M, K and n on Velocity Profile (f), When Q=2, Sc=0.23, R=2, Gr=2, Gm=2, N=2, S=2 and Pr=071

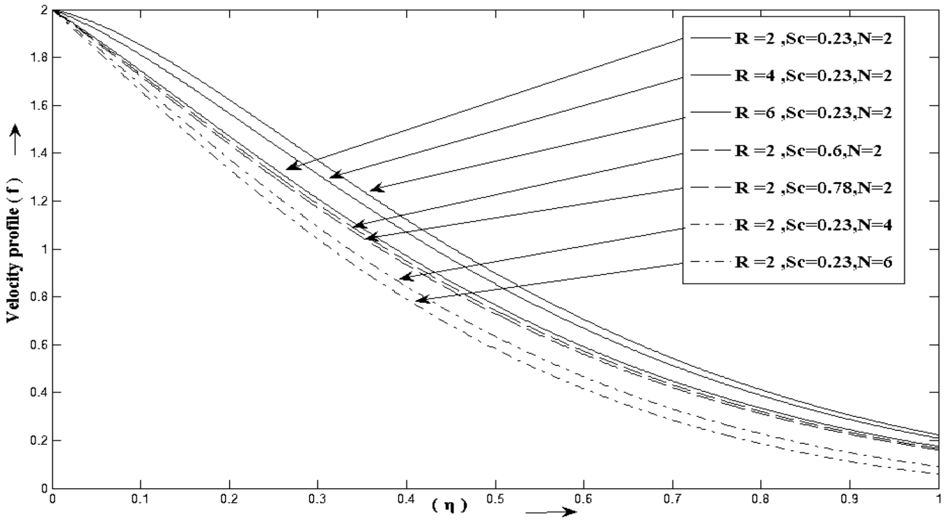

Figure 3: Effect of R, Sc and N on Velocity Profile (f), When Q=2, Sc=0.23, M=2, Gr=2, Gm=2, K=2, S=2 and Pr=071

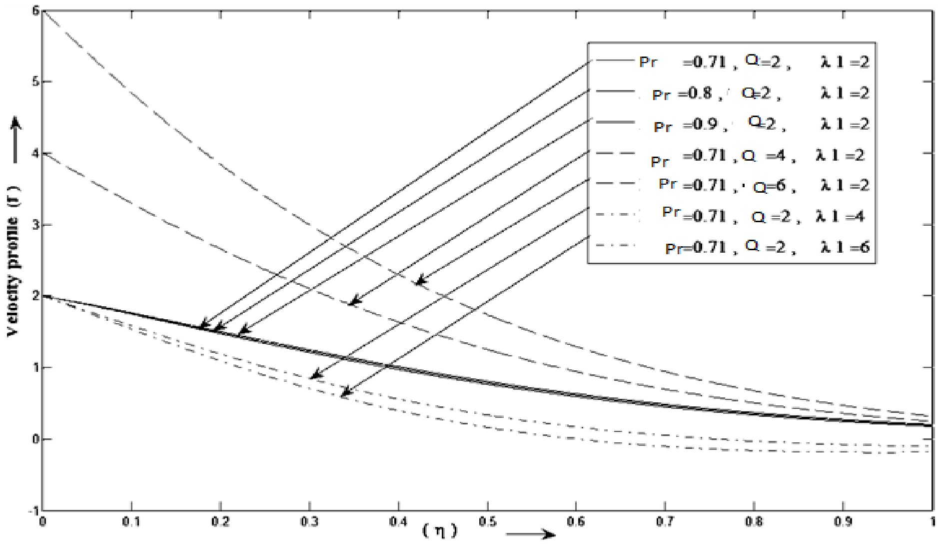

Figure 4: Effect of Pr, Q and λ_1 on Velocity Profile (f), When R=2, Sc=0.23, M=2, Gr=2, Gm=2, K=2, S=2 and Pr=071

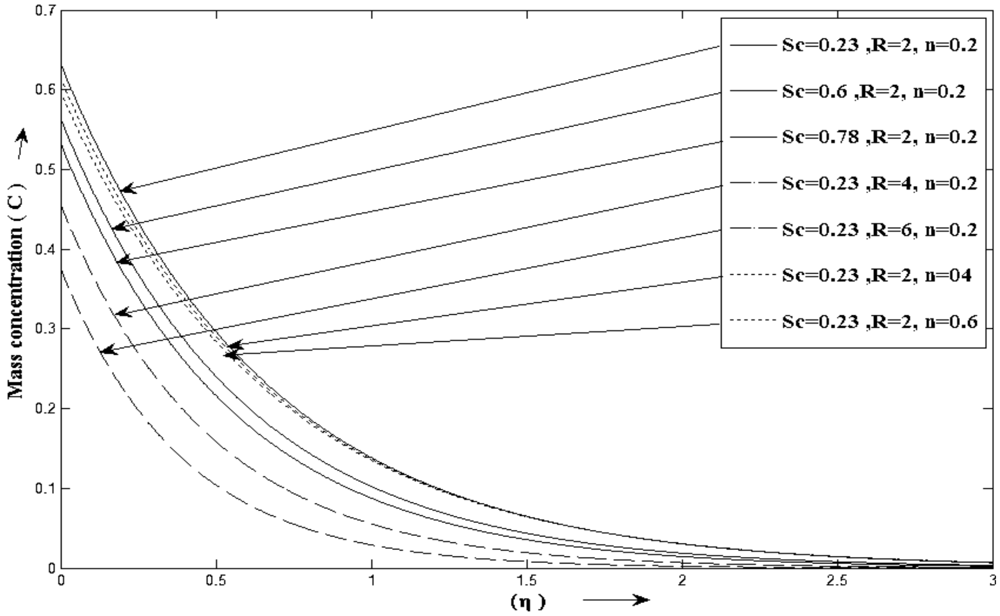

Figure 5: Effect of Sc, R and n on Mass Concentration Profile (C), When Other Parameters are Absent

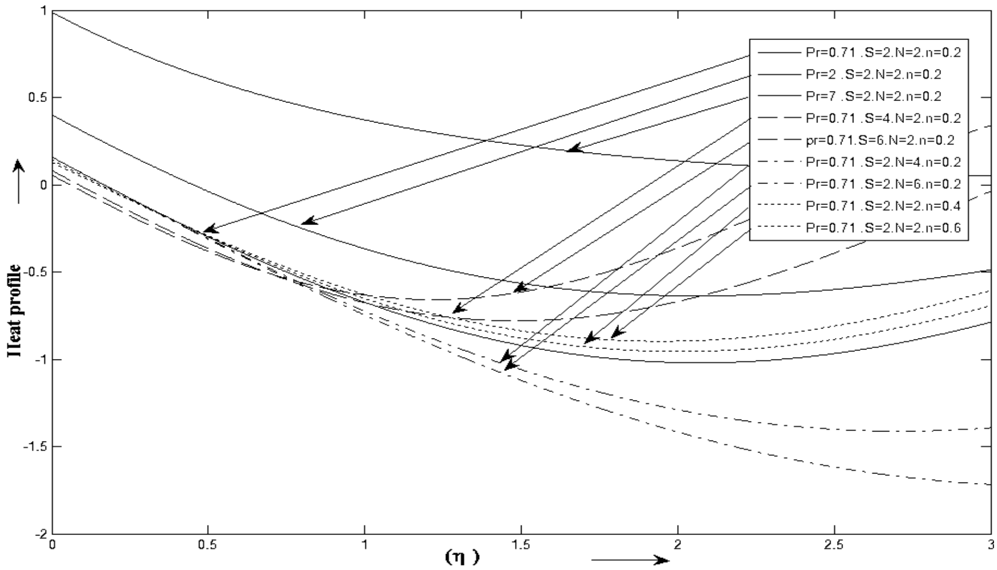

Figure 6: Effect of Pr, N, n and S on Heat Profile (θ), When Other Parameters are Absent

Table 1: Effect of Different Parameters on Shearing Stress

When n=2 K=2,Q=2,$S=2$,$N=2$, and Sc=0.23					Shearing Stress(τ)	When Pr=0.71,Gr=2,Gm=2,M=2,K=2 and R=2					Shearing Stress(τ)
Pr	Gr	Gm	M	R		Sc	S	N	n	Q	
0.71					2.6837	0.23					2.6837
0.8					2.6643	0.6					2.7709
0.9					2.4161	0.78					2.8499
	4				2.5903		4				0.8150
	6				2.5681		6				0.4967
		4			5.0672			4			3.4909
		6			7.9452			6			3.7623
			4		6.6770				4		6.4111
			6		8.2826				6		12.8181
				4	2.7203					4	4.3933
				6	3.2038					6	6.5878

REFERENCES

1. K. Vajravelu and K. S Sastri Free convective heat transfer in a viscous incompressible fluid confined between a long vertical wave wall and a parallel flat plate, J. Fluid Mechanics vol-86 Part (II) 365–383, 1978.

2. M. Vedhanayagam, R. A. Altenkirch, R. Eichhorn, A transformation of the boundary layer equation for free convection flow past a vertical flat plate with arbitrary blowing and wall temperature variation, Int. J. Heat Mass Transfer, 23, 1236–1288, 1980.

3. S.T. Revankar, Natural convection effects on MHD flow past an impulsively started permeable plate, Indian J. pure Appl. Math., 14, 530–539, 1983.

4. P. Mohapatra and N. Senapati, Steady magneto hydrodynamic free convection flow through a porous medium with mass transfer. Reg.J. Heat Energy Mass transfer, 6(4), 297-304,1984.

5. P. Mohapatra and N. Senapati, Magneto hydrodynamic unsteady free convection flow with mass transfer through a porous medium, J. NationalAcad. of Mathematics, 5,49-65,1987.

6. P. Mohapatra and N. Senapati hydrodynamic free convection flow with mass transfer past a vertical plate AMSE, 37(1), 1-23, 1990.

7. Vashney N. K. and Giri, Jaykesh, Effect of Kuvshinshki fluid on MHD free convection flow through a porous medium boundaded by an oscillating porous plate in slip flow regime with heat source/sink and transpiration, Jour. PAS.Vol.15 (Math.Sc.), p.102 (2009).

8. N. Senapati and R. K. Dhal, magnetic effect on mass and heat transfer of a hydrodynamic flow past a vertical oscillating plate in presence of chemical reaction, AMSE, B-2, 79(2):60-66, (2011).

9. N. Senapati, R. K. Dhal and T. K. Das, Chemical reaction effects on MHD free convection poiseuille flow and mass transfer through a porous medium bounded by two infinite vertical porous plate. ISST journal of mathematics and computing system, vol-3(1),:56-67, (2012).